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Brown

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[54] **ENVIRONMENTAL STRESS SCREENING PROCESS WITH LIQUID COUPLED VIBRATION**

[75] Inventor: **Edwin Z. Brown**, Westminster, Colo.

[73] Assignee: **AT&T IPM Corp.**, Coral Gables, Fla.

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[51] **Int. Cl.**[6] **G01M 7/00**

[52] **U.S. Cl.** **73/571**; 73/662

[58] **Field of Search** 73/662, 664, 571, 73/577

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,278,241	3/1942	Case	73/662
4,733,151	3/1988	Butts	73/664
5,039,228	8/1991	Chalmers	73/662
5,187,432	2/1993	Bauernfeind et al.	324/158

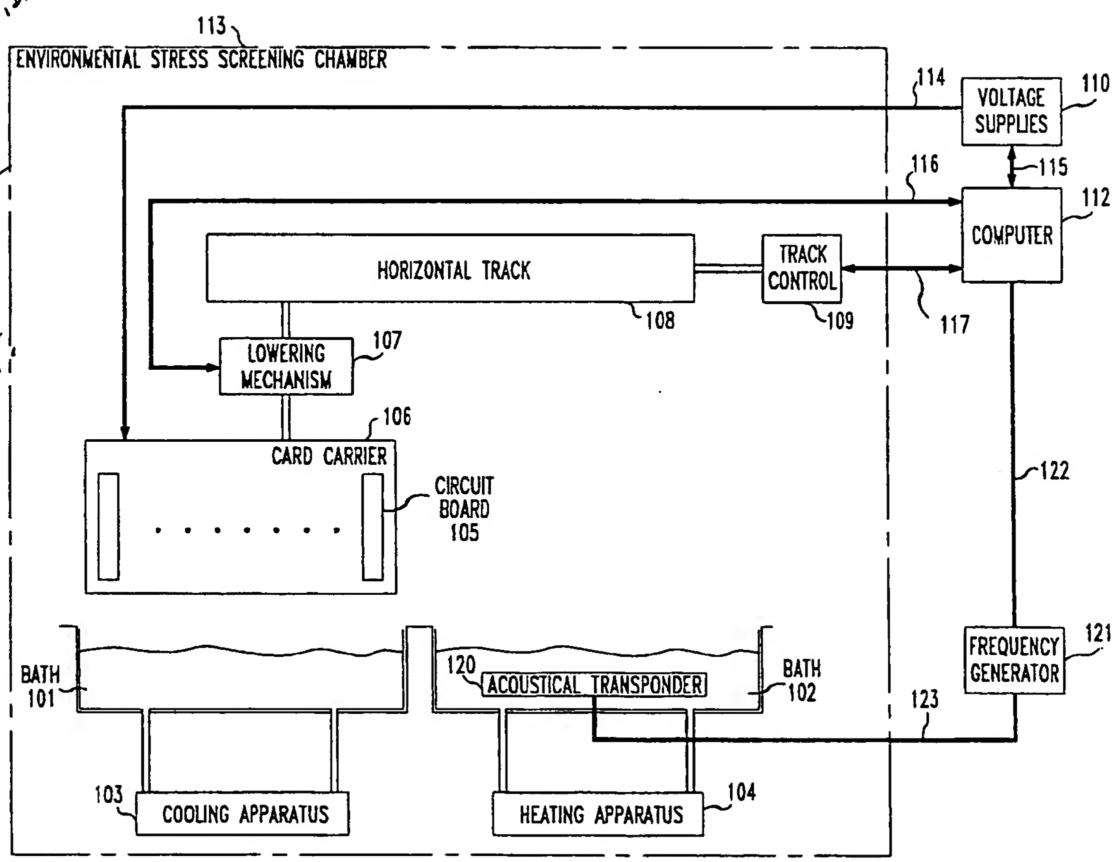
Primary Examiner—Richard Chilcot
Assistant Examiner—Max H. Noori
Attorney, Agent, or Firm—John C. Moran

[57] **ABSTRACT**

A testing system for stressing assembled circuit boards well beyond normal operational limits with respect to mechanical vibration, supply voltage cycling, and temperature cycling. The combination of these three elements of stressing results in each of the three elements accelerating the effects of the other two elements. The circuit boards are transferred between a cold bath of inert liquid and a hot bath of inert liquid while power voltages are applied for short periods of time at voltages which exceed the normal voltages of the devices and vibrations are introduced into the inert liquid. The vibrations scan a broad range of frequencies thus accelerating the effect of the hot bath. In particular, in the hot bath, the use of ultrasonic frequency greatly accelerates the speed at which components are induced to absorb heat. The vibrations allow the detection of potential failures in the wire bonding of integrated circuits. The testing system allows for the integration of both vibration, supply voltage, and temperature stressing in one integrated work station allowing the goals of a just-in-time manufacturing process to be achieved.

4 Claims, 3 Drawing Sheets

10% excess V
temp baths - vibrate
apply/disc V
no proc test



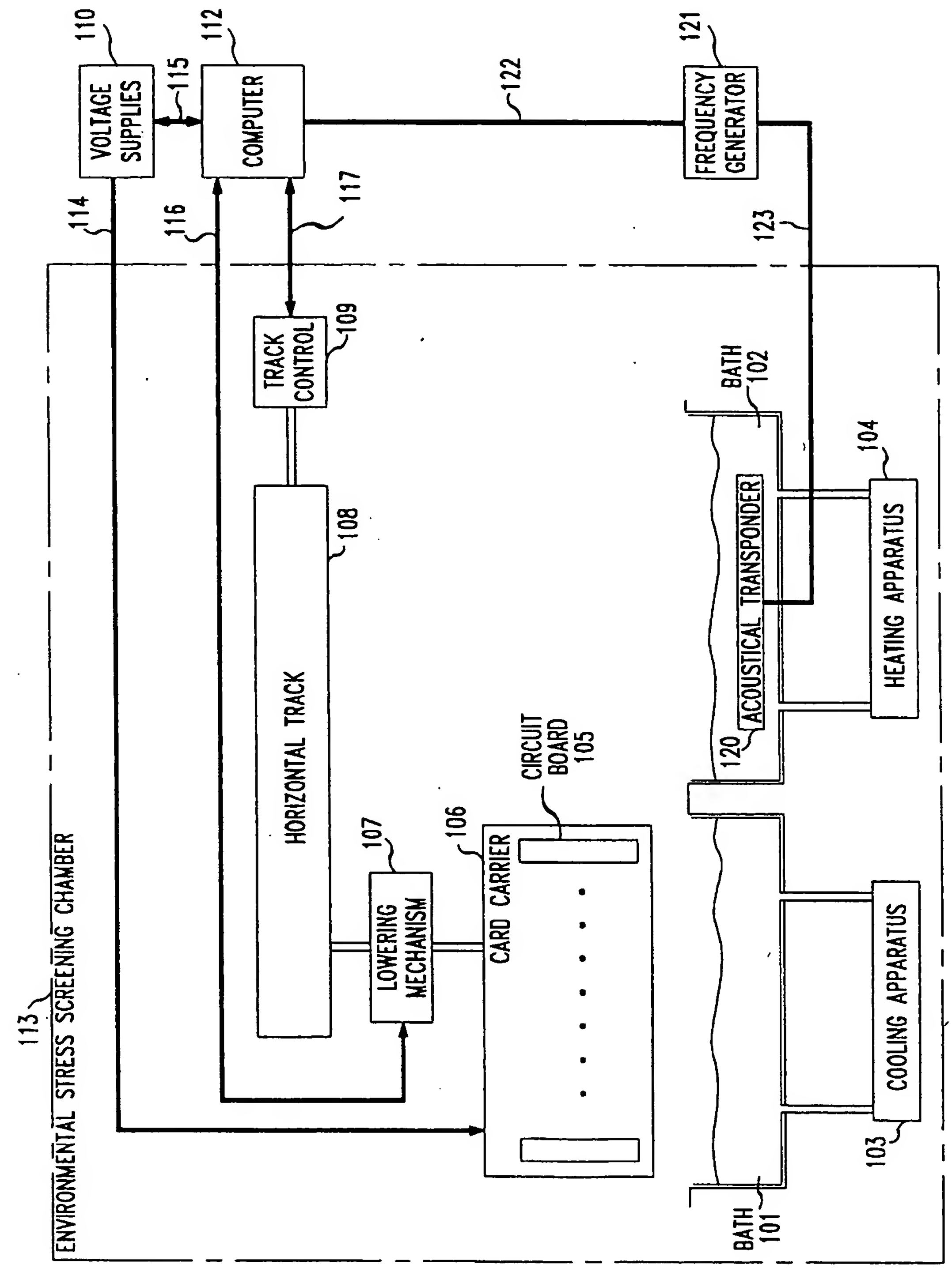

VOLTAGE SUPPLIES
110
COMPUTER
112
115
FREQUENCY GENERATOR
121
122
114
116
117
123
TRACK CONTROL
109
HORIZONTAL TRACK
108
LOWERING MECHANISM
107
CARD CARRIER
106
CIRCUIT BOARD 105
BATH 102
ACOUSTICAL TRANSPONDER
120
HEATING APPARATUS
104
COOLING APPARATUS
103
BATH 101
ENVIRONMENTAL STRESS SCREENING CHAMBER
113

FIG. 1

FIG. 2

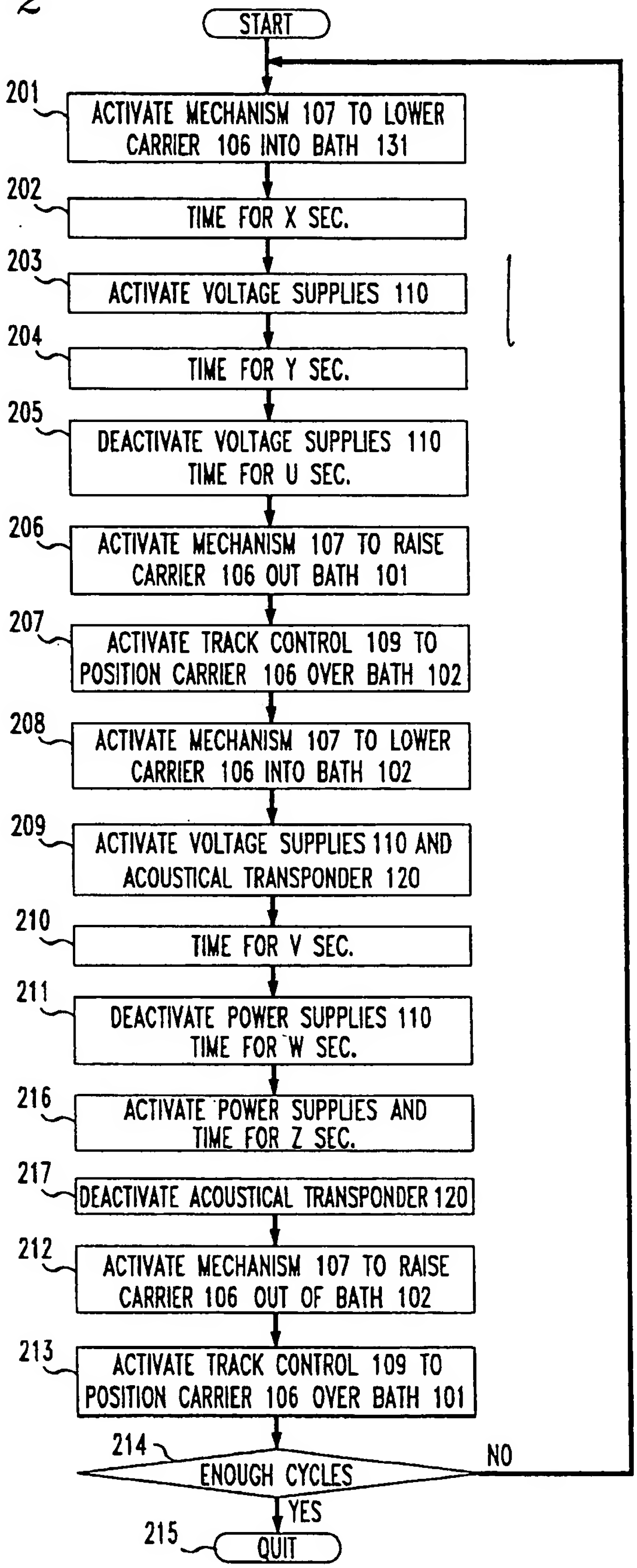

START
201 ACTIVATE MECHANISM 107 TO LOWER CARRIER 106 INTO BATH 131
202 TIME FOR X SEC.
203 ACTIVATE VOLTAGE SUPPLIES 110
204 TIME FOR Y SEC.
205 DEACTIVATE VOLTAGE SUPPLIES 110 TIME FOR U SEC.
206 ACTIVATE MECHANISM 107 TO RAISE CARRIER 106 OUT BATH 101
207 ACTIVATE TRACK CONTROL 109 TO POSITION CARRIER 106 OVER BATH 102
208 ACTIVATE MECHANISM 107 TO LOWER CARRIER 106 INTO BATH 102
209 ACTIVATE VOLTAGE SUPPLIES 110 AND ACOUSTICAL TRANSPONDER 120
210 TIME FOR V SEC.
211 DEACTIVATE POWER SUPPLIES 110 TIME FOR W SEC.
216 ACTIVATE POWER SUPPLIES AND TIME FOR Z SEC.
217 DEACTIVATE ACOUSTICAL TRANSPONDER 120
212 ACTIVATE MECHANISM 107 TO RAISE CARRIER 106 OUT OF BATH 102
213 ACTIVATE TRACK CONTROL 109 TO POSITION CARRIER 106 OVER BATH 101
214 ENOUGH CYCLES
NO
YES
215 QUIT

FIG. 3

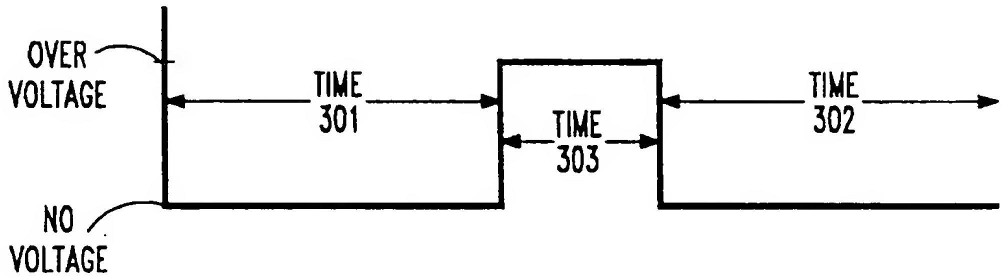
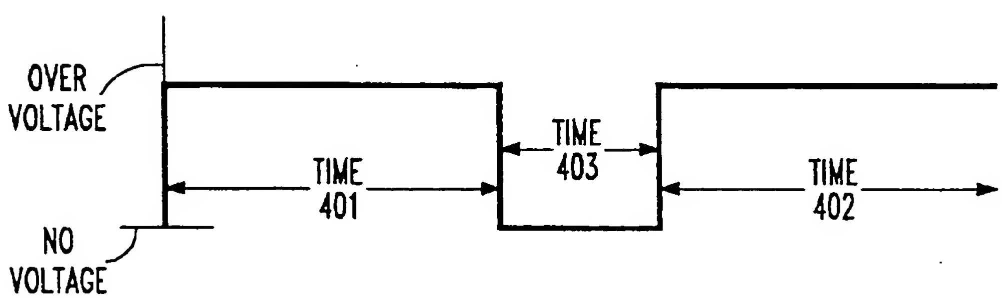

OVER VOLTAGE
NO VOLTAGE
TIME 301
TIME 303
TIME 302

FIG. 4


OVER VOLTAGE
NO VOLTAGE
TIME 401
TIME 403
TIME 402

ENVIRONMENTAL STRESS SCREENING PROCESS WITH LIQUID COUPLED VIBRATION

TECHNICAL FIELD

The present invention relates to environmental screening of electronic circuit boards.

BACKGROUND OF THE INVENTION

A well known problem in the manufacturing of electronic circuit boards is early failures which are referred to as infant failures. Statistically, the majority of the electrical devices that will fail in the first ten years will fail during the first year of operation. To reduce these failures and associated warranty cost, manufacturers perform burn-in tests. Such tests can eliminate the majority of the electrical devices that will fail during the first year of operation. During a burn-in test, the devices are subjected to elevated thermal or electrical operating conditions for a long period of time, typically, one to eight weeks, thereby simulating one year of operation under normal conditions.

In the prior art, U.S. Pat. No. 5,187,432 stresses assembled circuit boards well beyond normal operational limits both with respect to supply voltages and temperature cycling. The circuit boards are transferred between a cold bath of inert liquid and a hot bath of inert liquid while the power voltages are being applied for short periods of time at voltages which may exceed the normal voltages of the devices. The circuit boards are transferred rapidly between the hot bath to the cold bath and vice versa and maximum stresses are achieved without damaging parts or circuit boards.

Whereas the testing method set forth in U.S. Pat. No. 5,187,432 performs the functions of a burn-in test, there still exists a class of flaws which can only be accelerated into observable failures by doing mechanical vibration stressing. Prior art mechanical vibration stressing has consisted of placing equipment on mechanical shaker tables and mechanically moving the whole electrical apparatus. Whereas such vibration testing does perform the mechanical vibration stressing, it is not compatible with high velocity manufacturing and just-in-time (JIT) processes. The JIT process requires that the various parts needed to build a complex piece of electronic gear such as a modern telecommunications system arrive at the manufacturing plant almost simultaneously and that the complete electronic system is produced in a matter of days, often as short as four or five days. Since a large amount of time is required to assemble circuit boards, there is a limit on how many different stages of testing can be performed. Each additional stage introduced into the JIT process adds to the delay in producing the final product. In addition, the JIT process requires that individual components of the electronic system be tested separately. The most complex component in the electronic system is the printed circuit packs. Prior art vibration techniques of testing each circuit pack individually on shaker tables would cause additional delays.

Hence, there exists a long felt need among electronic system manufacturers for a method that combines burn-in and vibration testing in a simple integrated testing method.

SUMMARY OF THE INVENTION

The foregoing problems are solved by a method and apparatus that involve stressing assembled circuit boards well beyond normal operational limits with respect to mechanical vibration, supply voltage cycling, and temperature cycling. The combination of these three elements of stressing results in each of the three elements accelerating the effects of the other two elements. The circuit boards are transferred between a cold bath of inert liquid and a hot bath of inert liquid while power voltages are applied for short periods of time at voltages which exceed the normal voltages of the devices and vibrations are introduced into the inert liquid. The vibrations scan a broad range of frequencies thus accelerating the effect of the hot bath. In particular, in the hot bath, the use of ultrasonic frequency greatly accelerates the speed at which components are induced to absorb heat. Advantageously, the vibrations allow the detection of potential failures in the wire bonding of integrated circuits. Most importantly, this new method and apparatus allows for the integration of both vibration, supply voltage, and temperature stressing in one integrated work station allowing the goals of a JIT process to be achieved.

Vibration T + V

Other and further aspects of the present invention will become apparent during the course of the following description and by reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 illustrates, in block diagram, form the environmental screening chamber for practicing the invention;

FIG. 2 illustrates, in flow chart form, a program to control the environmental testing chamber; and

FIGS. 3 and 4 illustrate the manner in which supply voltages are applied to circuit boards during the stress process.

DETAILED DESCRIPTION

FIG. 1 illustrates, in block diagram form, environmental stress screening chamber **113** which is controlled by computer **112**. Card carrier **106** contains a plurality of circuit boards such as circuit board **105** which are going to be stressed. By controlling frequency generator **121**, computer **112** introduces mechanical vibrations into bath **102** by exciting acoustical transducer **120**. The mechanical vibrations set up in the inert liquid of bath **102** accelerate mechanical flaws in the circuit boards under test to determine failures. The vibrations introduced are swept from approximately 20 Hz to 100 kHz. The ultrasonic frequency vibrations (20 kHz to 100 kHz) not only induce mechanical failures but also excite molecules within electronic components of the circuit boards so that the thermal and electrical stresses occur faster or are more penetrating. With the faster occurrences of those stresses within the limits of the circuit boards, late or intermittent problems are more apt to become observable defects that can be detected and removed. The ultrasonic frequencies can be varied quickly and easily.

Computer **112** controls the power voltages for the circuit boards in card carrier **106** by controlling voltage supplies **110** which supply voltage to card carrier **106** via cable **114** and vibrations by controlling acoustical transducer **120** via frequency generator **121**. The stressing method is to first insert card carrier **106** into bath **101** by actuation of lowering mechanism **107** by computer **112**. Bath **101** is referred to as the cold bath and advantageously may be maintained at a temperature ranging from −5° C. to −20° C. After the card carrier **106** is in bath **101** for a predefined amount of time, computer **112** actuates voltage supplies **110** to apply extreme voltages as illustrated in FIG. **3** to the circuit boards within card carrier **106**. As illustrated in FIG. **3**, no voltages are

control V

applied until time **303**. During time **301**, the circuit boards are allowed to reach the temperature of bath **101**. This is done to simulate the "arctic" condition which can occur when power is first applied to a system. After card carder **106** has been in bath **101** for time **303**, voltages are removed from card carder **106**. After time **302**, card carrier **106** is removed from bath **101** by actuation of lowering mechanism **107** and positioned over bath **102** by actuation of horizontal track **108** by track control **109** under control of computer **112**. Bath **102** is referred to as the hot bath and advantageously may be maintained at a temperature ranging from 50° C. to 85° C.

Card carrier **106** is then lowered into bath **102** by actuation of lowering mechanism **107**. As soon as card carrier **106** is submerged in bath **102**, computer **112** actuates voltage supplies **110** via cable **115** to supply extreme voltages and actuates frequency generator **121** via cable **122** to control acoustical transducer **120** to sweep a range of frequency and vibration intensifies, as illustrated in FIG. 4. After card carrier **106** has been in bath **102** for time **401**, voltage supplies **110** are deactivated for time **403**. After time **402**, acoustical transducer **120** is deactivated and card carder **106** is removed from bath **102** and repositioned back over bath **101**. After this cycle has been performed for the designated number of times, card carder **106** is removed from the environmental stress screening chamber **113** and is replaced by another card carder having a new set of circuit boards to be processed. After being stress tested in environmental stress screening chamber **113**, an operational test is performed on each circuit pack in card carder **106** to determine if each circuit pack is still fully operational.

Environmental stress screening chamber **113** is illustrated only in block diagram form and does not show the mechanism for recovering the inert liquids in bath **101** and **102** which will be released into the interior of the screening chamber.

FIG. **2** illustrates, in flowchart form, a program for controlling computer **112**. At the start of each cycle, block **201** is executed to activate lowering mechanism **107** so that carrier **106** is placed into bath **101**. Block **202** then times for X seconds which advantageously may be 30 seconds (time **301** of FIG. 3). After this time has elapsed, block **203** is executed to actuate voltage supplies **110** to increase the nominal 5 volts supply up to 7.5 volts and the other voltages are increased up to 10% above their nominal value. This amount of voltage increase is far in excess of the normal operating margins allowed on the power voltages.

10% above Nominal

After block **204** has timed for Y seconds (time **303** of FIG. 3) which may be 5 seconds, block **205** is executed to deactivate voltage supplies **110**. After U seconds (time **302** of FIG. 3) has elapsed, block **206** actuates mechanism **107** to raise card carder **106** out of bath **101**, and block **207** is actuated so that track control **109** repositions card carder **106** over bath **102**. U may be 25 seconds.

Block **208** is then executed to lower card carder **106** into bath **102**. As soon as card carrier **106** is submerged in bath **102**, block **209** is activated to supply the high voltages to the circuit boards in card carrier **106** and to generate vibrations by acoustical transducer **120**. Block **210** then times for V seconds (time **401** of FIG. 4) which may be 30 seconds. At the end of this time period, block **211** is executed to deactivate voltage supplies **106** and time for W seconds (time **403** of FIG. 4) which may be 5 seconds. After V seconds, block **216** activates voltage supplies **110** to supply over voltage for Z seconds (time **402** of FIG. 4) which may be 30 seconds. After Z seconds, voltage supplies **110** are deactivated, block **216** is executed to deactivate acoustical transducer **120**, and block **212** is executed to raise the card carrier **106** from bath **102**. Finally, block **213** is executed to activate track control **109** to position card carder **106** over bath **103**. Decision block **214** is executed to determine if enough cycles have been performed. If enough cycles have been performed, block **215** is executed to quit the stress process on this particular card carder, and the operator is given time to remove the card carrier from the environmental stress screening chamber **113** and to replace this card carrier with a new card carder. If enough cycles have not been performed, then block **201** is executed to commence the execution of the stress screening test on card carrier **106**. The number of cycles may be 9. Testing has shown that the time required to transfer card carder **106** from bath **101** to bath **102** should be less than 18 seconds.

Acoustical transducer **120** is illustrated as a single unit; however, in order to generate vibrations in the frequency range from 20 Hz to 100 kHz acoustical transducer **120** could be two separate transducer units. The first transducer unit which would sweep in the low frequencies advantageously would be a transducer unit similar to Model 1411 that is manufactured by Advance Sonic Processing, Inc. The transducer for the ultrasonic range advantageously would be a Prosonic unit manufactured by Ney, Inc. or a Model 750 manufactured by UFI, Inc. The lower frequency starts at 20 Hz with a power density of 4 to 5 watts per square inch. Similarly, the upper frequency starts at 20 kHz with the power level being 4 to 5 watts. In addition, whereas acoustical transducer **120** is illustrated at the bottom of bath **102**, the acoustical transducer could be located anywhere in bath **102**.

It is to be understood that the above-described embodiment is merely illustrative of the principles of this invention; other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention. In particular, one skilled in the art could readily envision using an acoustical transducer in bath **101** to induce vibrations into the circuit boards under test at the cold temperatures. Further, other vibration frequencies and intensities could be utilized. Similarly, different voltage ranges may be used for the voltage power supplies. Also, the number of cycles may be varied.

I claim:

1. An environmental stress testing system for stress testing circuit boards mounted in a carder, comprising:

a hot inert liquid bath that is maintained at a temperature of in excess of 50° C.;

a cold inert liquid bath that is maintained at a temperature of less than –0° C.;

a controller for controlling the environmental stress testing system;

apparatus for transferring the carder between the cold inert liquid bath and the hot inert liquid bath under control of the controller;

power supplies for applying maximum power voltages to the circuit boards in the carrier under control of the controller;

an acoustical transducer system for applying mechanical vibrations to the circuit boards via the hot inert liquid bath and the acoustical transducer system comprises a first and second acoustical transducers with the first acoustical transducer producing low frequency mechanical vibrations in response to the electrical frequency signals with the resulting mechanical vibrations in a range of 20 Hz to 20 kHz and the second

acoustical transducer producing high frequency mechanical vibrations in response to the electrical frequency signals with the resulting mechanical vibrations in a range of 20 kHz to 100 kHz so that not only are mechanical failures induced but also molecules within electronic components are excited incurring faster, and more penetrating thermal and electrical stresses; and

a frequency generator for applying electrical frequency signals to the acoustical transducer system to control the mechanical vibrations produced by the acoustical transducer system with the frequency generator being controlled by the controller.

2. The environmental stress testing system of claim 1 wherein the first and second acoustical transducers apply mechanical vibrations of 4 to 5 watts per square inch.

3. A method for screening electronic circuit boards mounted in a carrier to detect potential infant failures, the method comprises the steps of:

(A) immersing the carder in a cold bath of an inert liquid that is maintained at a temperature of less than –0° C.;

(B) applying power supply voltages to the electronic circuit boards in excess of the maximum operational voltages upon a first predefined period of time elapsing;

(C) removing the power supply voltages from the electronic circuit boards;

(D) transferring the carder from the cold bath to a hot bath of the inert liquid that is maintained at a temperature of in excess of 50° C. within a second predefined period of time;

(E) applying the power supply voltages to the electronic circuit boards in excess of the maximum operational voltages as the carder is immersed in the hot bath;

(F) applying mechanical vibrations via the inert liquid to the electronic circuit boards with a first range of mechanical vibrations being in the range of 20 Hz to 20 kHz and a second range of mechanical vibrations being the range of 20 kHz to 100 kHz so that not only are mechanical failures induced but also molecules within electronic Components are excited incurring faster and more penetrating thermal and electrical stresses;

(G) removing the power supply voltages and mechanical vibrations from the electronic circuit boards; and

(H) repeating steps A through G for predefined number of cycles.

4. The method of claim 3 wherein mechanical vibrations applied have power range of 4 to 5 watts per square inch.

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